Evaluation of User Experience Goal Fulfillment: Case Remote Operator Station

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Abstract. In this paper, the results of a user experience (UX) goal evaluation study are reported. The study was carried out as a part of a research and development project of a novel remote operator station (ROS) for container gantry crane operation in port yards. The objectives of the study were both to compare the UXs of two different user interface concepts and to give feedback on how well the UX goals experience of safe operation, sense of control, and feeling of presence are fulfilled with the developed ROS prototype. According to the results, the experience of safe operation and feeling of presence were not supported with the current version of the system. However, there was much better support for the fulfilment of the sense of control UX goal in the results. Methodologically, further work is needed in adapting the utilized Usability Case method to suit UX goal evaluation better.

Keywords: remote operation, user experience, user experience goal, evaluation.

1 Introduction

Setting user experience (UX) goals, which are sometimes also referred to as UX targets, is a recently developed approach for designing products and services for certain kinds of experiences. While traditional usability goals focus on assessing how useful or productive a system is from product perspective, UX goals are concerned with how users experience a product from their own viewpoint [1]. Therefore, UX goals describe what kind of positive experiences the product should evoke in the user [2].

In product development, UX goals define the experiential qualities to which the design process should aim at [2,3]. In our view, the goals should guide experience-driven product development [4] in its different phases. The goals should be defined in the early stages of design and the aim should be that in later product development phases the goals are considered when designing and implementing the solutions of the product. In addition, when evaluating the designed product with users, it should be assessed whether the originally defined UX goals are achieved with it.

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In the evaluation of UX goals in the case study reported in this paper, we have utilized a case-based reasoning method called Usability Case (UC). For details about the UC method, see for example [5]. In order to test empirically how the method suits the evaluation of UX goals, we used it to conduct an evaluation of UX goals of a remote operator station (ROS) user interface (UI) for container crane operation. Next, the details of the evaluation study case and the utilized UC method are described.

2 The Evaluation Study Case

Our case study was carried out as a part of a research and development project of a novel ROS for container gantry crane operation in port yards. These kinds of remote operation systems exist already in some ports of the world and are used for example for the landside road truck loading zone operation of semi-automated stacking cranes.

Both safety and UX aspects motivated the case study. Firstly, taking safety aspects into account is naturally important in traditional on-the-spot port crane operation as people's lives can be in danger. However, it becomes even more important when operating the crane remotely, because the operator is not physically present in the operation area and for example, visual, auditory, and haptic information from the object environment is mediated through a technical system. Secondly, although UX has traditionally not been in the focus of complex work systems development, it has recently been discussed as a factor to be taken into account in this domain also (e.g., [6]).

Hence, the aim of our project was to explore ways to enhance the UX of the remote crane operators by developing a novel ROS operation concept, which also takes into account the required safety aspects. To achieve this aim, we defined UX goals and user requirements based on an earlier field study by us. The field study (for details, see [7]) was conducted in two international ports and included operator interviews and field observations of their work. The UX goals were created in the beginning of the project and then utilized in guiding the design work throughout the development of the new ROS. In addition, altogether 72 user requirements (when counting both main and sub requirements) were defined and connected to the created UX goals.

The overall UX theme for the new ROS was defined to be 'hands-on remote operation experience'. The four UX goals to realize this theme were chosen after a deliberate process to be 'experience of safe operation', 'sense of control', 'feeling of presence', and 'experience of fluent co-operation'. Details about how these goals were chosen and what they mean in practice regarding the developed system can be found in [2] and [3]. In the evaluation study of the ROS reported in this paper, the experience of fluent co-operation goal could not be included as the functionalities supporting co-operation between different actors in operations were not yet implemented to the ROS prototype and the participants conducted the operations individually.

The main objectives of the conducted evaluations were twofold. Firstly, we wanted to compare the user experience of two optional ROS user interface concepts, which were developed during the project. Secondly, we strived to receive data from the evaluations on how well the UX goals experience of safe operation, sense of control, and feeling of presence are fulfilled with the current ROS prototype system.

2.1 The Study Setting

The evaluations were conducted with a simulator version of the ROS system, which was operated with two industrial joysticks and a tablet computer (see Fig. 1 for a concept illustration). A 32-inch display placed on the operator's desk provided the main operating view, which included virtual reality (VR) camera views and simulated, but realistic operational data (e.g., parameters related to the weight of a container).

Fig. 1. Concept illustration of the ROS system with the four-view setup in the main display

The main display's user interface consisted of camera views and operational data provided by the system. In this display, two different user interface setups were implemented to the virtual prototype: a four-view (see Fig. 1 for a simplified concept illustration version) and a two-view setup. Wireframe versions of the layouts of these two user interface setups for the main operating display can be seen in Fig. 2.

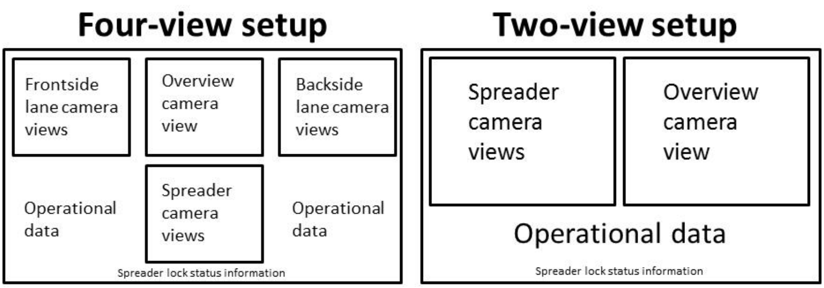

Fig. 2. Wireframe versions of the two alternative main display setups of the concepts

Operation Tasks in Remote Container Crane Operation. Semi-automated gantry cranes in ports are operated manually for example when lifting or lowering containers from and to road trucks, which are visiting the port. These operations happen physically in a specific area called the loading zone. The cranes are operated manually from an ROS after the spreader (device in the cranes used for lifting and lowering the containers) reaches a certain height in the loading zone during the otherwise automated operation. The remote operator utilizes real-time data and loading zone cameras to ensure that the operation goes safely and smoothly.

User Interface of the Four-view Setup. The user interface of the four-view setup (Fig. 1) included four distinct camera views: 1) overview camera view (top-middle), 2) spreader camera view (bottom-middle) that combined pictures of the four cameras attached to the corners of the spreader, 3) frontside lane camera views (top-left), and 4) backside lane camera views (top-right). Both of the lane camera views combined two video feeds from the corners of the truck into one unified view. Three separate camera views could be changed to the overview camera view: an area view (seen in the top-middle view of Fig. 1), a trolley view (a camera shooting downwards from the trolley), and a booth view (a camera showing the truck driver's booth in the loading zone). On the left and right side of the spreader camera view, different types of operational data were displayed.

User Interface of the Two-View Setup. The user interface of the two-view setup (see Fig. 2) consisted of only two, but larger camera views than in the four-view setup: the spreader camera view on the top-left side and the overview camera view on the top-right side. Both of these views could be easily changed to show the relevant camera view at each phase of the task. To the left-side view, also the lane camera views could be chosen. To the right-side view, the aforementioned area, trolley and booth views could be chosen. Under the camera views, there were several crane parameters and different status information displayed in a slightly different order than in the four-view setup.

Control Devices of the Concepts. The joystick functions of the two- and the four-view concepts varied. In the joystick functions of the four-view concept, the left joystick's functions were related to the overview camera (e.g., zoom, pan, and tilt) and for moving the trolley or the gantry. The right joystick was used for special spreader functions such as trim, skew, opening/closing the twist locks (that keep the container attached from its top corners to the spreader), and moving the spreader up- and downwards.

In the two-view concept, the joystick functions were optimized for the operation of the two camera views: the left joystick had controls related to the spreader view (e.g., skew and moving the spreader) and the right joystick to the overview view (e.g., the aforementioned camera operations).

On the tablet, located between the joysticks, there were functions for example for changing the different camera views: in the four-view concept there was only a possibility to change the top-middle overview view while in the two-view concept it was possible to change both the left and right side camera views. In addition, the received task could be canceled during operation or finalized after operation from the tablet.

2.2 Participants

In total, six work-domain experts were recruited as participants for the evaluation study. Three of them had previous experience in remote crane operation. All subjects were familiar with the operation of different traditional container cranes: two of them had over ten years of experience of operating different types of industrial cranes, three of them had 1-5 years of experience, and one of them had 6-10 years of experience.

2.3 Test Methods

In order to evaluate how the originally defined UX goals and user requirements are fulfilled with the evaluated prototype, we used a combination of different methods. During a one evaluation session, the participant was first interviewed about his experience and opinions regarding crane operation. Then, the participant was introduced to the developed prototype system and asked to conduct different operational tasks with the two alternative concepts of the system.

The test tasks included container lifting and landing operations to and from road trucks in varying simulated conditions. The first task was for training purposes and included a very basic pick-up operation; its aim was to learn to use the controls and the simulator after a short introduction to them. To support the joystick operation, the participants received a piece of paper describing the function layouts of the joysticks.

The other operation tasks were more challenging than the first one, and included different disruptive factors, such as for example strong wind, nearly similarly colored container chassis as the container to be landed, other containers in the surrounding lanes, a truck driver walking in the loading zone, and a locked chassis pin. These tasks were conducted with both of the concepts, but not in the same order.

The two different concepts (the four- and the two-view concepts) were tested one at a time. The order of starting with the two-view or with the four-view concept was counterbalanced. Therefore, every other user started first with the two-view concept and every other with the four-view concept.

A short semi-structured interview was conducted after each operational task. In addition, two separate questionnaires were used to gather information: the first one about the user experience and the second one about the systems usability [8] of the concepts. The UX questionnaire consisted of twelve user experience statements that were scaled with a 5-point Likert scale. The UX questionnaire was filled in when the test participants had completed all the tasks with either of the concepts. Ultimately, the UX questionnaire was filled in regarding both of the concepts.

In the end of the test session, some general questions related to the concepts were asked before the participants were requested to select the concept that they preferred and that in their opinion had a better user experience. Finally, a customized systems usability (see e.g., [8]) questionnaire was filled in for the selected concept. The systems usability questionnaire included thirty-one statements that were also scaled with a five-point Likert scale. Due to space restrictions, neither of the abovementioned questionnaires is presented in detail in this paper.

The test leader asked the participants to think-aloud [9], if possible, while executing the operation tasks. The think-aloud protocol was utilized to make it easier for the researchers to understand how the participants actually experience the developed concept solutions. The evaluation sessions were video recorded to aid data analysis.

2.4 Analysis

The ultimate aim of the evaluations was to assess whether the chosen UX goals were fulfilled with the VR prototype version of the system. To do this, we utilized the Usability Case method, because we wanted to explore the suitability of the method for this kind of research. UC provides a systematic reasoning tool and reference for gathering data of the technology under design and for testing its usability in the targeted work [10]. The method applies a case-based reasoning approach, similar to the Safety Case method [11]. Throughout the development process, the UC method creates an accumulated and documented body of evidence that provides convincing and valid arguments of the degree of usability of a system for a given application in a given environment [5]. The main elements of UC are: 1) *claim(s)* (nine main claims of systems usability [8], of which three are related particularly to UX) that describe an attribute of the system in terms of usability (e.g., "User interface X is appropriate for task Y"), 2) *subclaim(s)* describing a subattribute of the system that contributes to the main claim (e.g., "X should work efficiently), 3) *argument(s)* that provides ground for analyzing the (sub)claims (e.g., "It is possible to quickly reach the desired result with X"), and 4) *evidence*, which is the data that provides either positive or negative proof for the argument(s) (e.g., task completion times in usability tests) [5].

In line with the UC method, the data gathered from our studies was carefully analyzed regarding each defined user requirement (i.e., a subclaim in UC) on whether positive or negative cumulative evidence was found about the fulfillment of each requirement. This fulfilment was based on the arguments derived from the evidence. On the basis of the fulfilment of different user requirements, it was possible to determine whether a certain UX goal (i.e., a claim in UC) is fulfilled or not. If most of the user requirements connected to a certain goal were met, then also the UX goal could be said to have been fulfilled. In addition to this kind of evidence-based reasoning, the UC method also provided us with data on the usability and UX of the concepts under evaluation. These results support the design work by providing feedback for future development.

3 Results

The results of our studies are presented in the following order: First, we present general user experience and usability related results that affected the chosen UX goals regarding both the four- and the two-view concepts. Then, we discuss which of the concepts the participants chose in the end of the test sessions and why. Finally, we discuss whether the defined UX goals were fulfilled and make hypotheses on what were the underlying reasons for these results.

3.1 Notes on General UX and Usability of the Concepts

Four-view Concept. In general, the participants felt that the information provided by the main display's four-view setup was appropriate and understandable: for example, the participants commented that the amount of presented camera views at once was suitable and most of the necessary information was available for the basic crane operations. However, some of the participants felt that for example information about possible fault conditions concerning the crane were missing from the current solution.

While performing the test tasks, the participants utilized most frequently the area and the spreader camera views. The spreader camera view was experienced to be useful especially at the beginning of a lifting task. However, when the spreader approached the container, it became more difficult to understand the position of the spreader in relation to the container in detail. In addition, the participants thought that the provided lane camera views did not support the beginning phase of the container pick-up operations, because the participants could not clearly comprehend the orientation of the provided views until the spreader was seen moving in the views.

Regarding the joystick functions in the four-view concept, the placement of some functions was not reported to support the operations very well. For example, the positions of the skew and trim functions were not optimal, since participants made frequent mistakes with them and reported to get emotionally frustrated with them. In addition, the position of the zoom was proposed to be placed together with the steering functions, i.e., to be designed into the right-hand joystick.

The overall nature of the results of the UX questionnaire statements related to sense of control with the four-view concept was positive. The participants felt that they were able to start, conduct, and stop the operations at their own pace. In addition, according to the interviews, the provided joysticks were experienced to be suitable for the remote operation of cranes and the feel of the joysticks to be robust enough. Also, the crane's reactions to the joystick movements was experienced to be appropriate.

Nevertheless, the UX goal feeling of presence did not get as much supportive results as sense of control. This was mostly due to the problems identified with the solutions aimed to fulfil requirements concerning the operation view. For example, the four-view concept's camera views were experienced to be too small for the participants to easily see everything that was necessary. In addition, combining two camera views together (in the lane cameras) received negative evidence; the participants had difficulties to orientate themselves with the combined camera views and perceive to which direction each of the cameras was shooting at.

The experience of safe operation with the four-view setup was reported to be negatively affected by the presentation layout of the operational parameters. For example, the grouping of the information was not experienced to be in line with a typical task flow of one operation.

Two-view Concept. The two-view setup in the main display was generally experienced to be clearer than the four-view concept according to the participants' thinking-out-loud comments and interviews. For example, the camera views were found to be big enough to spot relevant things from the object environment. Especially the area view was utilized a lot during the operations, because it offered a possibility to see better the spreader in relation to the container.

With the two-view concept the users felt that all the needed operational information was available and in a logical order (i.e., in line with a typical task flow of one operation). The participants for example mentioned that it was possible to perceive easily the status of the operation with one glance from this information.

The UX questionnaire results concerning statements related to sense of control with the two-view concept were positive, mostly due to the same reasons as they were with the four-view concept. In addition, these results showed that the participants felt that they were able to concentrate on a sufficient level on performing their operations with the two-view concept.

However, the UX goal feeling of presence received somewhat negative results from the tests. For example, the participants had difficulties to perceive the operation view provided through the different combined camera views. As with the four-view setup, especially the views of the combined camera views of spreader and lane cameras were experienced to be hard to understand what is seen from them. In addition, the camera views were not reported to support the comprehension of depth and different distances between objects in the loading zone very well.

Furthermore, the results regarding requirements connected to the provided camera views were fairly negative. Some of the participants commented that due to the placement of the camera views they were not able to see critical objects related to the task at hand through the camera views in the outmost truck lanes; for example, it was not possible to see easily all corners of the container and the truck's position. These results had a significant effect to the experience of safe operation UX goal.

3.2 Concept Selection

When asked at the end of the test session that which of the two concepts the participant preferred, four of the participants selected the two-view concept and two of them chose the four-view concept. Based on the participants' experience, the two-view concept was easier to understand: it was reported to be effortless to observe the loading zone through the big camera views and the provided operational information was said to be placed in a logical order. However, according to the participants, some of the joystick functionalities were placed better in the four-view concept than in the two-view concept.

In general, it can also be said that the results of the systems usability questionnaire were fairly positive regarding the both concepts. These results were further utilized in the analysis of fulfillment of the defined user requirements and UX goals described in the next section.

3.3 Fulfilment of User Requirements and UX Goals

Most of the user requirements were not fulfilled on a comprehensive level with neither the four- nor the two-view setups of the current prototype system. Especially the evidence related to the user requirements that were connected to the UX goals experience of safe operation and feeling of presence was mostly negative. Therefore, it can be said that these two goals were not fulfilled with the current versions of the ROS's two- and four-view concepts.

The experience of safe operation was affected for example by the fact that the participants were not able to form a clear picture of the situation in the loading zone when handling the container in the outmost truck lanes. Therefore, they needed to manually adjust the cameras a lot in order to gain a better view to the position of the truck and corners of the container. In addition to the aforementioned factors, the overview camera was not experienced to be sharp enough (when zoomed in) for the participants to be able to see whether the truck's chassis' pins are locked or unlocked when starting a lifting operation. An obvious danger to safety from this problem is that if the pins are locked when starting a container lifting operation, also the truck will be lifted to the air with the container.

The feeling of presence UX goal was negatively affected for example by the fact that some of the camera views (e.g., lane cameras) were difficult for the participants to understand and orientate themselves into. Furthermore, understanding distances between different objects in the loading zone was not experienced to be sufficient with the current camera views. In addition, some of the default zooming levels of the cameras were not very optimal for the conducted task in question and the participants had to do a lot of manual zooming. In Fig. 3, we provide an example of the used Usability Case-based reasoning regarding negative evidence for one requirement connected to the UX goal feeling of presence.

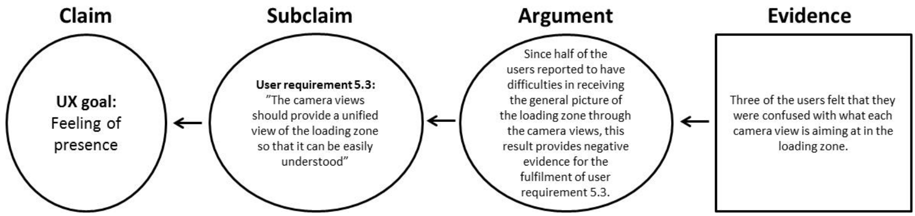

Fig. 3. Example of Usability Case based reasoning in our analysis.

The example of evidence in Fig. 3 was negative comments from three different participants while conducting the tasks with the ROS. In general, other than verbal evidence (the thinking-out-loud comments or the interview answers) provided by the participants were for example the results of the (UX and systems usability) questionnaires and task performance indicators. All this data was considered when creating the final Usability Case, which cannot be described here entirely due to its large size.

Regarding the sense of control UX goal, there was clear positive evidence in the end results from both of the concepts. For example, the utilized joysticks were felt to be robust enough and to control the crane with an appropriate feel of operation. Overall, the participants felt that they were able to master the crane's operations and concentrate on the task at hand. In addition, the possibilities to freely decide when to start and stop operating and to easily adjust the speed of operation with the joysticks were felt to be positive features. Therefore, it can be said that sense of control was achieved with both of the evaluated concepts.

4 Discussion

The results indicate that the evaluated concepts had both positive and negative aspects. The design of the final concept solution should be based on the positive aspects taken from both of the evaluated concepts. From the two-view concept, especially the placement of the operational data and size of the camera views should be adopted to the final concept. From the four-view concept, for example the layout of the joystick functions regarding the basic crane movements should be utilized.

In general, the results confirmed that providing real-time camera feeds for this kind of remote operation is essential. Visual validation of the situation in the object environment allows taking into consideration possible extra variables affecting the operation, such as weather conditions or debris on top of the container to be lifted up. Therefore, good quality camera views could support the experience of safe operation and feeling of presence goals with the final system.

The ecological validity of the prototype system also needs to be discussed as it may have had an effect to the UX goals. First, the fact that the operations with the system were not happening in reality, had an obvious effect on the participants' user experience and attitude towards the operations; if for example the people seen in the object environment would have been real human beings instead of virtual ones, the participants could have been more cautious with the operations. This fact had an obvious effect especially to the experience of safe operation UX goal.

Second, the virtual camera views cannot of course correspond to real camera views from the object environment. This had an obvious effect on the feeling of presence UX goal. However, it must be noted that some of the test participants thought that the virtual simulator was near equal to a real remote crane operation system, since the provided virtual camera views were implemented with such a good resolution. The simulator was also reported to provide a relatively precise feel of the operation, but did not for example have as much swaying of the container as it would have in real operations.

Third, the fact that in real life there are truck drivers with whom the operators communicate through the phone in case of problems affected the ecological validity of the conducted tasks. In addition, the participants conducted the tasks individually in a small room, which is not the case in real remote crane operation work. Therefore, as in real conditions the work is actually much more social than in our evaluation study, this had an obvious effect on the validity of the results of the studies.

5 Conclusions

The conducted study did not give an exact answer to the question, which one of the concepts should be selected for future development. Both concepts had positive factors that should be taken into account when designing the final system.

Different camera views provided essential information from the operating area. A decision concerning the amount of cameras in the loading zone and the camera views provided in the ROS needs to be made for the final concept to support safe crane operation. Another important factor is the size of the camera views in the main display. The two-view setup was experienced to have large enough views for the operation. A balance between the amount and size of the views presented in the user interface needs to be found. If the display space of a one monitor does not allow to present big enough camera views, then the possibility of two monitors needs to be considered.

To some extent, it was possible to evaluate the user experience of remotely operated crane operations with our virtual simulator even though the camera views were not real. However, the user experience of the system was not the same as if it was when operating in a real work environment. For example, the sounds, tones, or noises from the operating environment were not in the focus of the concept development or this evaluation study. In the final system's development, careful attention should be paid to the auditory information provided by the system from the object environment.

In general, as most of the user requirements related to the UX goals feeling of presence and experience of safe operation were not supported by the evidence from the evaluation studies, it can also be said that the originally defined main UX theme of 'hands-on remote operation experience' was not yet fulfilled with the current prototype system. In the future development, the requirements that were not met should be taken under careful investigation and answered with sufficient solutions. In this way, also the defined UX goals could be met better with the final system.

Nevertheless, the evidence from our study results supported the fulfillment of the UX goal sense of control for both of the concepts. Especially the feeling of the joystick operation and reactions of the crane were experienced to be appropriate and realistic. Support for aiming the spreader and the container to the correct position could enhance the sense of control even more in the future versions of the UI.

In the future development of the ROS, special attention should also be paid to the experience of fluent co-operation UX goal and different aspects related to it (e.g., the interaction between the co-workers and the truck drivers) as in the present study it was not possible to address this goal appropriately. Therefore, future studies with the system should include for example several test participants operating simultaneously with the system in order for the operational setting to be more realistic. To increase the ecological validity of the results, a more comprehensive study with a wider range of data inquiry methods could be carried out in a real control room setting with actual operators. This kind of a study could be conducted by adding some features of the proposed concept to the current, already implemented ROS solutions at some port and then evaluating whether the new features are useful and make the work more pleasant.

Methodologically, this paper has contributed to the discussion on how UX goals can be evaluated. According to the results, although the evaluated concepts were still in quite early stages of their design, the Usability Case method seemed to suit to this kind of UX goal evaluation with some modifications. Firstly, further work is needed especially on linking the arguments regarding the user requirements to the detailed design implications (for details see e.g., [3]) of the UX goals. Secondly, a scoring method for the evidence provided by study data should be implemented to the UC method in general, so that more emphasis could be placed on the data concerning the most critical parts of the evaluated product. Finally, it should be experimented whether other than the utilized data gathering methods could provide relevant data in constructing the Usability Case and studied how the method supports also later phases (than just the early-stage evaluation) of UX goal driven product development.

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